Open-source and open-workflow Climate Scenarios Toolbox for adaptation planning

CDI FY19 Full Proposal

Lead PI Information

PI Name: Aparna Bamzai
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PI ORCID: 0000-0002-2444-9051
PI Organization: USGS North Central Climate Adaptation Science Center
PI Mission Area: Land Resources
PI City, State: Fort Collins, CO

Plain Language Summary

This project will provide an open source workflow in R, called the Climate Scenarios Toolbox, to help researchers, climate service providers, and resource management partners access and interpret relevant climate data, assess resource vulnerabilities to climate variability and change, and design adaptation strategies. The Toolbox will facilitate a rapid assessment of future climate scenarios based on a wide variety of climatic metrics and a high flexibility to manipulate timescales and geographic domain, filling a critical gap in existing analytic tools and solving a data integration challenge experienced by USGS and its partners. The investigator team is committed to creating a framework surrounding the Toolbox to support an open community of practice and foster community-driven improvements to future versions in order to increase access to and the usability of existing climate datasets.

Financial Information

Total Requested Funds: 29600
In-Kind Matching Funds: 30841

Project Information

Project Description: The investigator team proposes to develop and implement the Climate Scenarios Toolbox, a seamless R-code workflow to ingest historic and projected climate data and generate a set of summary information and customizable graphics for a user-specified region of interest. The Toolbox will solve a data integration challenge experienced by USGS and its partners and will increase access to and the usability of existing climate datasets.
List of Anticipated Deliverables: Git Hub repositories for the two R packages, written guidelines for using the Climate Scenarios Toolbox, and initial development of a community of

practice. We anticipate submitting to rOpenSci for publication in Journal of Open Source Software or Methods in Ecology and Evolution.
SSF Element 1: Publishing / Sharing
SSF Element 2: Analysis
SSF Element 3: Processing

Collaborators

	Name	**City**	**State**	**Organization**
Co-PI	Brian Miller	Fort Collins	CO	USGS North Central Climate Adaptation Science Center
Co-PI	Brian Johnson	Boulder	CO	University of Colorado - Boulder
Co-PI	Max Joseph	Boulder	CO	University of Colorado - Boulder
Co-PI	Imtiaz Rangwala	Boulder	CO	University of Colorado - Boulder
Collaborator	John Gross	Fort Collins	CO	NPS Climate Change Response Program
Collaborator	Gregor Schuurmann	Fort Collins	CO	NPS Climate Change Response Program
Collaborator	David Lawrence	Fort Collins	CO	NPS Climate Change Response Program

Proposal Narrative

A. Scope

The USGS National and Regional Climate Adaptation Science Centers[1] (CASCs) were established to aid DOI bureaus, Tribes, and other natural resource management agencies in planning for and adapting to the impacts of climate variability and change on fish, wildlife, and habitats. Global climate models are a key source of climate information and produce large amounts of spatially explicit data for various physical parameters. However, these projections have substantial uncertainties associated with them, and the datasets themselves can be difficult to work with. CASC management partners often use scenario planning as a structured process for grappling with uncertainty and its implications for resource management.

In climate change scenario planning, resource managers and scientists use climate projections to identify a small set (usually 3-5) of plausible, divergent scenarios that capture the range of uncertainty in future conditions. Examples of identified future climate scenarios - based on one North Central CASC project[2] and shown in Figure 1 - include (1) hot and dry, (2) moderately hot with no precipitation change, and (3) warm and wet conditions. In this case, these scenarios were identified by examining changes in annual temperature and precipitation around 2035 (2021-2050) relative to 1971-2000 for a particular geography in southwest Colorado. Summary statistics can then be generated for each scenario based on specific local resource concerns. Managers and scientists use this information in discussions to evaluate the potential impacts of climate change and identify appropriate and robust adaptation strategies.

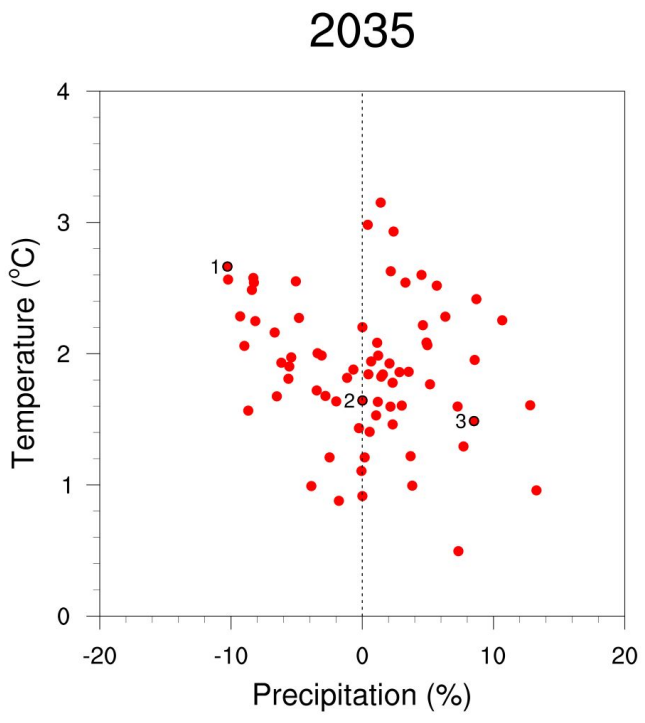

Figure 1: Example of future climate scenarios for a region of southwest Colorado. Axes represent changes in temperature and precipitation compared to long-term historic means. Red dots indicate individual global climate model results. Numbers indicate selected scenarios.

[1] https://casc.usgs.gov/
[2] https://www.sciencebase.gov/catalog/item/521ce597e4b01458f7857ff4

CASC resource management partners, such as the National Park Service (NPS) Climate Change Response Program, the Fish and Wildlife Service (FWS), and The Nature Conservancy (TNC), have expressed a recurring need for climate data summaries (graphics, tables, statistics) to use in scenario planning, as the process of selecting, acquiring, analyzing, and interpreting climate data is inherently complex and requires expertise beyond their capacity (see attached letters of support). There exists an opportunity to develop and implement an efficient and robust Climate Scenarios Toolbox to help management partners access and interpret relevant climate data, assess resource vulnerabilities to climate variability and change, and design adaptation strategies.

B. Technical Approach

The investigator team will develop and implement the Climate Scenarios Toolbox, which will enable R users to view scenarios of future changes in selected climate drivers by a particular time horizon and geographic region of interest. In response to user demand, the Toolbox will provide high flexibility in choosing historic and projected timescales for generating these scenario graphics. Based on these graphics, users will then be able to select particular scenarios (global climate model runs for specific representative concentration pathways). For the selected scenarios, the Toolbox will draw on high-quality historic data and the most recent high-resolution climate model projections to produce region-specific graphical and tabular summaries, processed datasets (for further analysis), and detailed descriptions of the mathematical calculations and assumptions used to produce the output. The Toolbox will provide summaries of the trends and seasonal and spatial patterns, as well as customizable graphics, for historic and future time periods. Users will be able to make key choices about parameters for summarizing and displaying data, such as the baseline period for comparison to projections and whether American or metric units should be reported.

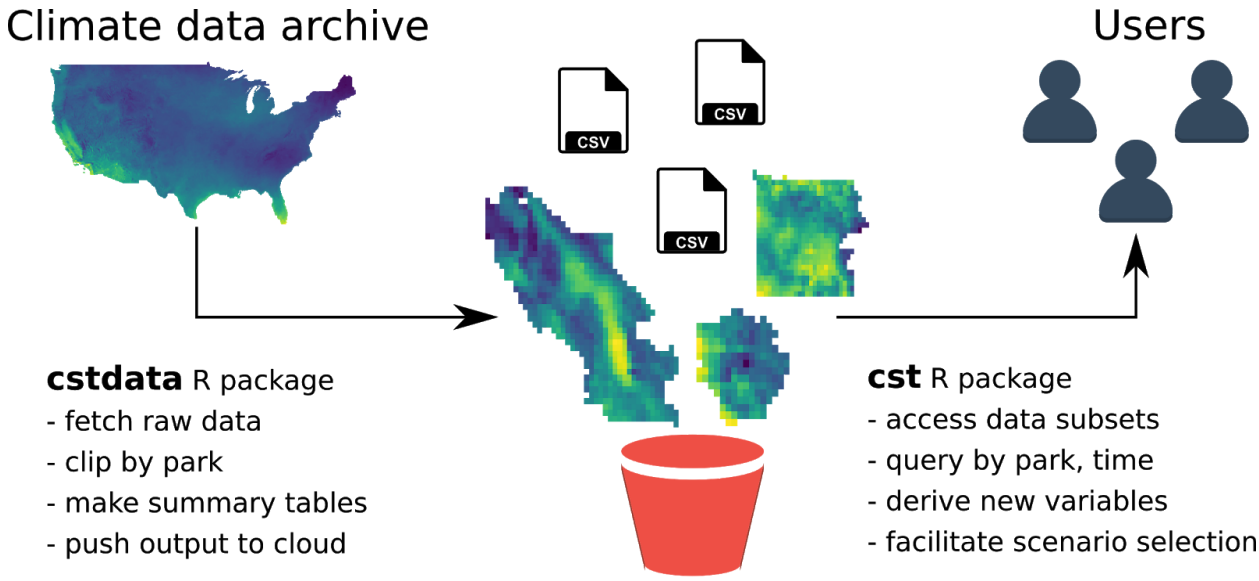

Figure 2: Schematic diagram of Climate Scenarios Toolbox functionality, including two R packages.

As shown in Figure 2, we propose to develop two R packages that meet different needs. First, the **cstdata** package will be primarily used by climate service providers with a technical background to access climate model data, clip data by spatial boundaries (shapefile), generate summary tables, and push output to cloud storage. Second, the **cst** package will be accessible to any user, including resource management partners, in order to output detailed information about the pre-processed and subset climate data. This package will allow users to rapidly acquire climate data for a region of interest from cloud storage (represented by the red bucket in Figure 2), eliminating the need to work with high volume climate data. The cst package will also include functionality to create derived variables. Facilitating access to these data will enable climate scenario selection and abstract away much of the complexity that is involved in working with extremely large climate simulation data.

The project team is committed to the implementation of all Tier 1 variables (as shown in Table 1) in version 1.0 of the Climate Scenarios Toolbox. Tier 2 variables represent an assortment of management-relevant climate information that has been requested by resource managers in previous North Central CASC scenario planning efforts. Approximately five Tier 2 variables will be selected for implementation in this phase of development in consultation with management partners and driven by an initial use-case.

A key goal for the investigator team is to create a framework surrounding the Toolbox to support an open community of practice and foster community-driven improvements to future versions. To meet this goal, R vignettes[3] (supplemental long-form documentation) will be produced for Tier 2 variables that walk the user through the purpose of each function, details of how it has been implemented, and realistic use cases for actual climate change scenario planning applications. These R vignettes will not only help users of the package and consumers of the produced information feel confident that each included variable has been derived correctly, but also provide templates to guide the community in expanding the future offering of Tier 2 variables.

We propose to use the Multivariate Adaptive Constructed Analogs[4] (MACA) dataset as the downscaled climate projections data source for version 1.0 of the Toolbox. This choice is based on open-source accessibility, high spatial resolution (4 km), and a more advanced downscaling methodology as compared to other available downscaled datasets. MACA data is available for 20 of the ~35 Global Climate Models that are part of the Coupled Model Intercomparison Project (CMIP) - Phase 5, and therefore it provides an adequate sampling of model uncertainty. It includes projections from both the moderate (RCP 4.5) and high (RCP 8.5) emissions scenarios. MACA data is available at a daily time step, which makes it particularly useful to capture changes in climate tendencies at that finer timescale, as well as derive (and quantify projected changes in) several relevant metrics that form the Tier 2 set of variables.

[3] http://r-pkgs.had.co.nz/vignettes.html
[4] https://climate.northwestknowledge.net/MACA/index.php

Climate Metric	Units	Units when describing change between periods	Timescales				Derived?
			Day	Month	Season	Year	
Tier 1 Variables							
Mean Temperature (Tmean)	degrees C,F	degrees C,F	☑	☑	☑	☑	☑
Maximum Temperature (Tmax)	degrees C,F	degrees C,F	☑	☑	☑	☑	
Minimum Temperature (Tmin)	degrees C,F	degrees C,F	☑	☑	☑	☑	
Precipitation	mm,in	%	☑	☑	☑	☑	
Humidity	kg/m^2	%	☑	☑	☑	☑	
Solar/Shortwave Radiation	W/m^2	W/m^2	☑	☑	☑	☑	
Wind Speed	mph	%	☑	☑	☑	☑	☑
Potential Evapotranspiration	mm,in	%	☑	☑	☑	☑	☑
Tier 2 Variables							
Last Day of Frost (i.e., last day in spring when Tmin<32F)	Julian day	days				☑	☑
First Day of Frost (i.e., first day in fall when Tmin<32F)	Julian day	days				☑	☑
#Extreme Hot Days (#days when Tmax greater than historical 99th percentile or a specific threshold value)	days	days		☑	☑	☑	☑
#Extreme Hot Nights (#days when Tmin greater than historical 99th percentile or a specific threshold value)	days	days		☑	☑	☑	☑
#Extreme Heat (#days when Heat Index greater than a particular value)	days	days		☑	☑	☑	☑
#Wet Days (#days when precip>1mm or 0.04in)	days	days		☑	☑	☑	☑
#Extreme Wet Days (#days when precip>50mm or 1in)	days	days		☑	☑	☑	☑
#Consecutive Dry Days (# consecutive days when precip<1mm or 0.04in)	days	days		☑	☑	☑	☑
Growing Degree Days [Tmax + Tmin)/2)-basetemp]	degrees F	degrees F				☑	☑
Growing season length (# days when Tmin>32F)	days	days				☑	☑
Growing Season Start GSS-first span of at least 6 days with daily Tmean > 5ºC	Julian day	days				☑	☑
Growing Season End GSE-first (after 7/1) span of at least 6 days with daily Tmean < 5ºC	Julian day	days				☑	☑
Severe Drought Frequency (PET crossing historic 95th percentile threshold)	count	%		☑	☑	☑	☑
Heat Index	-	-	☑			☑	☑
Heating Degree Days [18.3333-(Tmax+Tmin)/2]	degrees F	degrees F		☑	☑	☑	☑
Cooling Degree Days [(Tmax+Tmin)/2-18.3333]	degrees F	degrees F		☑	☑	☑	☑

Table 1: Tier 1 and Tier 2 variables for implementation in the Climate Scenarios Toolbox

MACA data has been widely used for ecological research and has been adopted by the U.S. Forest Service as the principal data for the 2020 Resources Planning Act Assessment. However MACA remains an onerous data set for resource managers to access and work with. Acquiring the daily data from the USGS GeoDataPortal and Google Earth Engine is challenging, especially when accessing large volumes of data. Additionally, the daily data require significant disk space and computing power to manipulate locally. By utilizing cloud storage, the Toolbox will generate smaller chunks of clean data subset by spatial unit and timer period, increasing stable access to the data.

The Toolbox will provide high flexibility to the user to choose specific timescales to assess a particular climate variable (e.g. how will the daytime high temperature in the month of June change by midcentury?) and will allow the user to examine a selected region based on a shapefile. Outputs will include GeoTIFFs of variables that MACA provides and datasets (CSV files) of derived variables (not spatially explicit - averaged over the region of interest). In the future, the team plans to also provide GeoTIFFs of derived variables as part of the Toolbox output.

Management partners will play a key role in designing the Toolbox in order to maximize the utility of the tool and its output for climate adaptation planning and decision-making. In addition to input from a broad suite of collaborators from NPS, FWS, and TNC, we will develop the Toolbox directly in conjunction with a related, ongoing effort at Wind Cave National Park (NP). The North Central CASC has been working with NPS Climate Change Response Program and NPS Denver Service Center to co-develop and refine guidance for incorporating climate science and scenario planning into NPS planning processes on a national scale, particularly Resource Stewardship Strategies (RSS). RSS are long-range planning tools that NPS units use to achieve their desired natural and cultural resource conditions and that guide each park's full spectrum of resource-specific management plans and day-to-day management activities. Currently, North Central CASC staff (PIs Miller, Rangwala, Joseph) are engaged in the initial phases of scenario planning for the Wind Cave NP RSS. The timing of the Wind Cave NP RSS and proposed project are opportune; the project team will be able to ground Toolbox development in specific NPS needs, thereby ensuring the relevance of project deliverables to other RSS and similar resource management planning processes.

C. Project Experience and Collaboration

Several modules for the workflow already exist in R, but further work is needed to link these modules into a start-to-finish product and develop additional functionality. The investigator team proposes to hire two full-time summer graduate student contractors to complete and streamline the workflow. Co-PI Max Joseph will provide day-to-day technical supervision of the students, while the rest of the PI and collaborator team will provide high-level input on the workflow design and utility of the output. The team brings strong expertise in analytics, climate data, computing and visualization, open source software programming development, geospatial and temporal statistics, and climate change scenario planning (see attached CVs).

D. Sustainability, Outreach, and Communication

The Toolbox will solve a data integration challenge experienced by USGS and its partners and will increase access to and the usability of existing climate datasets. The Toolbox will be distinct from existing online tools for climate data visualization because it will be designed specifically to meet the needs of the resource management community and will be an open-source and open-workflow tool; others within the national and eight regional CASC centers and the broader community of practice will be able to contribute future modules that will allow users to summarize climate data in new and different ways as user needs evolve and new data become available.

Once we have a functional start-to-finish workflow for the Toolbox, we plan to expand its capabilities over time to include additional downscaled data and variables. Other potential data sources are BCSD, BCCA, and LOCA[5], statistical downscaling methods applied to a number of model projections from CMIP - Phase 3 and CMIP - Phase 5, some of which include additional land surface variables that may be of relevance to resource management challenges. By building an adaptive framework for data sources and making code open and accessible, the project team and community of practice will also be able to be responsive to the release of the next generation of CMIP - Phase 6[6] climate data sets in coming years.

A CASC working group of climate scientists and climate data providers has already been collaborating across the national and regional network for a number of years on approaches to providing climate services for resource managers. This working group is an existing user-base that the investigator team can work with to build a technical community of practice around the Toolbox. Support from CDI would provide the seed funding necessary to create the initial working pilot version of the Toolbox that other programmers within the community of practice will be able to extend in future years.

Anticipated products will include Git Hub repositories for the two R packages, written guidelines for using the Climate Scenarios Toolbox, and initial development of a community of practice around the Toolbox. All products will comply with the USGS Office of Science Quality and Integrity Instructional Memoranda. The team anticipates submitting the R package to rOpenSci[7] for publication in Journal of Open Source Software or Methods in Ecology and Evolution, both of which have rigorous review processes. The team will also make the Toolbox discoverable by disseminating information via the North Central CASC website, the National CASC website and electronic newsletter, and by sharing across other USGS platforms such as ScienceBase.

E. Budget Justification

Federal Personnel:

Match - two weeks of salary each for USGS PIs Bamzai and Miller ($10,280).

[5] https://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html
[6] https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6
[7] https://ropensci.org/

Contract/Collaborator Personnel:

Match - two weeks each of salary and fringe for University of Colorado - Boulder PIs Joseph and Rangwala ($13,351).

Requested - funds for two full-time USGS summer student contractors. Compensation is commensurate with the level of education and experience, as follows: $23.19 per hour for student who has completed a Bachelor's degree and one year of graduate school. Contracts anticipated to include 600 billable hours each between the 15-week summer period of 5/12/19-8/24/19 ($27,828).

Travel:

Requested - funds for the two USGS summer student contractors and one co-PI to attend a scenario planning workshop to gain first-hand experience of stakeholder needs. We anticipate that Wind Cave National Park will conduct a two-day scenario planning workshop in July 2019. Lodging in Hot Springs, SD, for three nights for three people at GSA rate is $1,026. Per diem in Hot Springs, SD, for two travel days and two full days for three people is $746. Travelers will carpool to Hot Springs, SD, with other USGS and NPS employees.

Note: investigator team is local to Boulder, CO, and will not need travel support for a representative to attend the 2019 CDI Annual Workshop.

Indirect costs:

Match - Indirect cost associated with salary and fringe match for University of Colorado - Boulder PIs Joseph and Rangwala at the federally negotiated on-campus research rate of 54% ($7,210).

F. Timeline

March-April: PI team and collaborators diagram code workflow and determine design specifications

May-August: student contractors work full-time on coding, regularly meet with collaborators for feedback, and attend Wind Cave scenario planning workshop

August-September: PI team and collaborators review and release code

September onwards: continue development of new features, nurture community of practice

Appendices

Required: CV(s) of Principal Investigator(s) that highlights relevance to the proposed work **(max. 2 pages each)**

Optional: CV(s) of other collaborator(s) that highlights relevance to the proposed work **(max. 2 pages each)**

Optional: Letters of support from USGS or outside partners indicating a clear need for this effort. Submissions may also include Memoranda of Understanding (MOU) and/or letters of support indicating commitment to the longevity of the project. **(max. 1 page each)**

Aparna Bamzai-Dodson
U.S. Geological Survey, North Central Climate Adaptation Science Center
University of Colorado, Earth Lab, 4001 Discovery Dr., Suite 348, Boulder, CO 80303
abamzai@usgs.gov || 970-889-1231

KEY AREAS OF EXPERTISE

Climate Science; Proposal and Report Development; Program and Grant Management

Aparna Bamzai-Dodson serves as the North Central Climate Adaptation Science Center Deputy Director for the U.S. Geological Survey. She is responsible for managing the day-to-day operations of the center and maintaining regular and efficient communication with the U.S. Geological Survey, the center's university host and five other consortium member institutions, other partners, and stakeholder groups. She manages multiple portions of the grant process with a variety of funding sources and coordinates project reporting and progress with researchers.

EDUCATION

University of Oklahoma — Doctorate in progress: Geography and Environmental Sustainability
Advisor: Dr. Renee McPherson
Dissertation topic: Evaluation approaches for co-produced knowledge for climate adaptation

University of California - Berkeley — Doctoral coursework completed: Earth and Planetary Science
Advisor: Dr. Inez Fung
Proposed dissertation topic: Controls on soil moisture-climate feedbacks

Duke University — Master of Environmental Management: Global Environmental Change, 2007
Advisor: Dr. Gabriele Hegerl
Thesis topic: Global changes in precipitation extremes

Virginia Tech — Bachelor of Science: Mathematics, Bachelor of Science: Statistics, 2003

RELEVANT PROFESSIONAL EXPERIENCE

North Central Climate Adaptation Science Center, U.S. Geological Survey, Boulder, CO
USGS Deputy Director, January 2017-Current

National Climate Adaptation Science Center, U.S. Geological Survey, Reston, VA
Acting Deputy Chief, May 2018-September 2018

South Central Climate Adaptation Science Center, University of Oklahoma, Norman, OK
University Assistant Director, March 2015-January 2017
Technical Coordinator, August 2012-March 2015

The Keck Hydrowatch Project, University of California-Berkeley, Berkeley, CA
Assistant Specialist, August 2007-August 2008

RELEVANT PROFESSIONAL DEVELOPMENT

2016 National Conservation Training Center Online Climate Academy
2015 North Central Climate Science Center Early Career Professional Foundational Science Training
2014 Univ. of Ok. - Foundations in Effective Leadership and Foundations in Management Academies

2014 Texas Tech University Climate Communications Workshop
2013 American Meteorological Society Summer Policy Colloquium
2008 Mathematical Sciences Research Institute Summer Graduate School Workshop on Climate Change

RELEVANT GRANTS, CONTRACTS, AND OTHER AWARDS

I have served as principal investigator (PI) or co-investigator (co-PI) on the following grants (* indicates relinquished PI role when entering into federal service):

2017 *Advanced Pheno-climatic Information System, co-PI (PI: J. Morisette); National Aeronautics and Space Administration; Current - $1,245,932
2016 *Characterizing Components of Uncertainty in Downscaled Climate Projection, co-PI (PI: R. McPherson); US Dept. of Interior - USGS; Completed - $94,380
2016 *Translational Science Support, co-PI (PI: R. McPherson); US Dept. of Interior - USGS; Completed - $75,520
2015 *REU Site: Real-World Research Experiences at the National Weather Center, co-PI (PI: D. LaDue); National Science Foundation; Current - $885,653
2015 *Online Climate Change Impacts Course, PI; US Dept. of Interior - USGS; Current - $144,132
2015 Online Climate Change Impacts Course, PI; Internal education grant from Oklahoma Space Grant Consortium (PI: V. Snowden); Completed - $48,342
2015 Regional Graduate Student, Post-Doc, & Early Career Research Training II, co-PI (PI: D. Rosendahl); US Dept. of Interior - USGS; Completed - $58,917
2013 Regional Graduate Student, Post-Doc, & Early Career Research Workshop, co-PI (PI: R. McPherson); US Dept. of Interior - USGS; Completed - $50,959

RELEVANT PROFESSIONAL AFFILIATIONS

Member, American Association of Geographers
Member, American Meteorological Society
Associate Member, American Association of State Climatologists
Member, American Geophysical Union

BRIAN W. MILLER

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RESEARCH INTERESTS

Actionable science, agent-based modeling, climate change impacts & adaptation, rangeland ecology, scenario planning, social-ecological systems, state-and-transition simulation modeling

PROFESSIONAL EXPERIENCE & APPOINTMENTS

2016 – Present: Research Ecologist, U.S. Geological Survey
2014 – Present: Staff, Dept. of Interior North Central Climate Adaptation Science Center
2014 – 2018: Research Scientist, Natural Resource Ecology Laboratory, Colorado State Univ.
2013 – 2014: Postdoctoral Fellow, Natural Resource Ecology Laboratory & North Central Climate Science Center, Colorado State University

EDUCATION

2007 – 2013: Ph.D., Ecology, University of North Carolina at Chapel Hill
2002 – 2005: B.A. (*summa cum laude)*, Ecology & Evolutionary Bio., U. of Colorado, Boulder

SELECT TECHNICAL TRAINING RECEIVED

A Stochastic Process Approach to Agent-Based Modeling and Simulation (Max Planck Institute of Demographic Research, Oct. 2015, 6 days)
Climate-Smart Conservation with Scenario Planning (National Conservation Training Center, Mar. 2015, 5 days)
Advanced Concepts in Landscape State-and-Transition Simulation Modeling (Apex Resource Management Solutions Ltd., September 2014, 1 day)

SELECT PROFESSIONAL GRANTS & AWARDS

2018-2019: "Refining Guidance for Incorporating Climate Science and Scenario Planning into National Park Service Resource Stewardship Strategies", USGS, Co-PI, $50K
2018-2019: "Climate Change Vulnerability Assessment in Support of Pike San Isabel and Arapaho Roosevelt National Forest Plan Revision", USDA, Co-I, $50K
2017-2019: "Advanced Phenology Information System", NASA, Co-I, $1,244,387
2017-2019: "Improving Projections of Wildlife and Landscapes for Natural Resource Managers", USGS, PI, $43,023
2017-2019: "Informing Climate Change Adaptation Planning in National Parks", USGS, Co-I, $74,840
2016: *Climate Adaptation Leadership Award for Natural Resources*, Honorable Mention, Joint Implementation Working Group of the Ntl. Fish, Wildlife, & Plants Climate Adaptation Strategy
2015-2017: "Scaling Climate Change Adaptation in the N. Great Plains through Ecoregional Climate Scenarios & Local Qualitative-Quantitative Scenario Planning Workshops", USGS, Co-PI, $144,254
2010-2011: "Drought resource management and pastoralist livelihood change: an examination of the social dynamics mediating conservation goals and outcomes", NSF, co-PI, $12K
2007-2010: Population & Environment Integrative Graduate Education & Research Traineeship (IGERT), NSF, Total funding ~$139K
2005: Outstanding Student of the College of Arts and Sciences, Univ. of Colorado at Boulder
2005: Chancellor's Recognition Award (4.0 cumulative GPA), Univ. of Colorado at Boulder

SELECT PEER-REVIEWED PUBLICATIONS

Miller BW, Symstad A, Schuurman G. 2019. Implications of future climate scenarios for Badlands National Park resource management. National Park Service Resource Brief. In Press.

Beeton T, McNeeley S, **Miller BW**, Ojima D. 2018. Grounding simulation models with qualitative case studies: Toward a holistic framework to make climate science usable for US public land management. *Climate Risk Management*, In Press.

Miller BW, Symstad A, Frid L, Fisichelli N, Schuurman G. 2017. Co-producing simulation models to inform resource management: a case study from southwest South Dakota. *Ecosphere* 8(12).

Symstad AJ, **Miller BW**, Friedman JM., Fisichelli NA, Ray AJ, Rowland E, Schuurman GW. 2017. Model-based scenario planning to inform climate change adaptation in the Northern Great Plains – Final report: USGS Open-File Report 2017–1129.

Symstad A, Fisichelli N, **Miller BW**, Rowland E, Schuurman GW. 2017. Multiple methods for multiple futures: integrating qualitative scenario planning and quantitative simulation modeling for natural resource decision making. *Climate Risk Management* 17:78-91.

Sofaer HR, Abatzoglou JT, Jarnevich CS, Talbert MK, Barsugli JJ, **Miller BW**, Morisette JT. 2017. Designing ecological climate change impact assessments to reflect key climatic drivers. *Global Change Biology* 23(7): 2537-2553.

Morisette J, Cravens AE, **Miller BW**, Jarnevich C, Talbert C, Talbert M. 2017. Crossing boundaries in a collaborative modeling workspace. *Society & Natural Resources* 30(9).

Miller BW, Frid L, Chang T, Piekielek N, Hansen A, Morisette JT. 2015. Combining State-and-Transition Simulations and Species Distribution Models to Anticipate the Effects of Climate Change. *AIMS Environmental Science* 2(2):400–426.

Miller BW. 2015. Using geospatial analysis to assess the influence of land-use change and conservation on pastoralist access to drought resources. *Nomadic Peoples* 19(1): 120-145.

Miller BW, Leslie PW, McCabe JT. 2014. Coping with natural hazards in a conservation context: resource-use decisions of Maasai households during recent and historical drought. *Human Ecology* 42(5):753-768.

Miller BW, Morisette JT. 2014. Integrating research tools to support resource management under climate change. *Ecology and Society* 19(3): 41.

Miller BW, Doyle MW. 2014. Rangeland management and fluvial geomorphology in northern Tanzania. *Geomorphology* 214: 366-377.

Miller BW, Caplow SC, Leslie PW. 2012. Feedbacks between conservation and social-ecological systems. *Conservation Biology* 26(2): 218-227.

Miller BW, Breckheimer I, McCleary AL, Guzmán-Ramirez L, Caplow SC, Jones-Smith JC, Walsh SJ. 2010. Using stylized agent-based models for population-environment research: a case study from the Galápagos Islands. *Population and Environment* 31(6): 401-426.

SELECT PROFESSIONAL AFFILIATIONS & ACTIVITIES

Invited Participant: USGS Powell Ctr. Workshop (2019), National Socio-Environmental Synthesis Center (SESYNC) Pursuit (In Revision)

Invited Committee Member: Rising Voices 6 & 7, National Climate Adaptation Science Ctr. Network Seminar Series (2017–), Nat. Resource Ecology Lab Strategic Planning (2015)

Reviewer (select): Biol. Cons., Cons. Biol., Ecol. Applications, Methods in Ecol. & Evol.

Instructor: USFWS Ntl. Cons. Trng. Ctr. (2014–); NASA App. Rem. Sens. Trng. (2017-2018)

Brian R. Johnson
Earth Lab/CIRES, Analytics Hub Director
University of Colorado UCB 611, Boulder, CO 80303
Ph: 303-735-4851; email: brian.johnson-1@colorado.edu

PROFESSIONAL PREPARATION

University of Wisconsin, Madison, WI, **B.S.**, Electrical Engineering, 1982
University of Wisconsin, Madison, WI, **M.S.**, Electrical Engineering, 1986
University of Michigan, Ann Arbor, MI, **Ph.D.**, Atmospheric and Space Sciences, 1993

APPOINTMENTS

USGS North Central Climate Adaptation Science Center, Deputy University Director (2018 to present), University of Colorado, Boulder, CO
Earth Lab Analytics Hub Director (2017 to present), University of Colorado, Boulder, CO
Program Manager (2014-2017), NASA National Snow and Ice Data Center, Boulder, CO
Senior Principal Systems Engineer (2011-2014), Raytheon IIS, Aurora, CO
Senior Research Scientist (2008-2011), National Ecological Observatory Network, Boulder, CO
Deputy Director of Earth Science Advanced Systems (2006-2008), Ball Aerospace, Boulder, CO
Principal System Engineer (2001-2006), Ball Aerospace, Boulder, CO
Project Scientist (1995-2001), National Center for Atmospheric Research, Boulder, CO
Postdoctoral Fellow (1993-1995), National Center for Atmospheric Research, Boulder, CO
Research Assistant (1989-1993), University of Michigan, Ann Arbor, MI
System Engineer (1987-1989), Westinghouse Electric, Corp., Baltimore, MD
Research Assistant (1984-1987), University of Wisconsin, Madison, WI
Antenna Engineer (1983-1984), Harris Corp., Melbourne, FL

PUBLICATIONS

Related Publications

Grzegorz Miecznik and **Brian R Johnson** (2015). Effects of line-of-sight motion on hyperspectral Fourier transform measurements, J. Appl. Remote Sens., (9) 043510; doi: 10.1117/1.JRS.9.095982.

Vierling, Lee & Martinuzzi, Sebastian & Asner, Gregory & Stoker, Jason & **Johnson, Brian**. (2011). LiDAR—providing structure, Frontiers in Ecology and the Environment. 9. 261-262. 10.2307/23034407.

Thomas U. Kampe, **Brian R. Johnson**, Michele Kuester, and Michael Keller (2010), NEON: The First Continental-Scale Ecological Observatory with Airborne Remote Sensing of Vegetation Canopy Biochemistry and Structure, J. Appl. Remote Sens., Vol. 4, 043510; doi: 10.1117/1.3361375.

Selected Other Publications and Products

Johnson, BR, J McGlinchy, M Cattau, M Joseph and V Scholl, 2018: Harnessing commercial satellite technologies to monitor our forests. *REMOTE SENSING AND MODELING OF ECOSYSTEMS FOR*

SUSTAINABILITY XV, Gao, W; Chang, NB; Wang, J: Vol. 10767Art. No. UNSP 1076702, issn: 0277-786X, ids: BL5WA, doi: 10.1117/12.2321648

Brian R. Johnson, Amanda Leon, Siri Jodha Singh Khalsa (2015). Data Management in the Era of a Rapidly Changing Cryosphere, Geoscience and Remote Sensing Symposium (IGARSS), IEEE International, doi: 10.1109/IGARSS.2015.7326028.

Keith S. Krause, Michele A, Kuester, **Brian R. Johnson**, Joel T. McCorkel, and Thomas U. Kampe (2011) Early Algorithm Development efforts for the National Ecological Observatory Network Airborne Observation Platform Imaging Spectrometer and Waveform LiDAR, Proc. Soc. Photo-Opt Instr. Eng., Vol. 8151.

Synergistic Activities

- NEON Airborne Observing Platform Technical Working Group (2018)
- Proposal Review Panelist for NASA (2006, 2007, 2008, 2010, 2016) and DOE (2013)
- Program Committee Member for SPIE Conference Session on Remote Sensing and Modeling of Ecosystems for Sustainability, 2014 to 2018.

Maxwell B. Joseph
Data scientist
4001 Discovery Drive
SEEC S348, 611 UCB
Boulder, CO 80309
(530) 574-6897
maxwell.b.joseph@colorado.edu

Professional Preparation:

University of California, Davis, CA, Wildlife Fish and Conservation Biology, B.S., 2008
University of Colorado, Boulder, CO, Ecology and Evolutionary Biology, Ph.D., 2016

Appointments:

April 2016- present, Data scientist, Earth Lab Analytics Hub
Oct 2018-present, Open science architect, USGS North Central Climate Adaptation Science Center

Products:

i) ***Closely Related***

- Joseph MB, Oakley M, Schira Z. 2016. smapr: An R package for acquisition and processing of NASA SMAP data. https://github.com/earthlab/smapr
- Joseph MB, Preston DL, Johnson PTJ. 2016. Integrating occupancy models and structural equation models to understand species occurrence. Ecology, 97(3). https://doi.org/10.1890/15-0833.1
- Mihaljevic JR, Joseph MB, Johnson PTJ. 2015. Using multi-species occupancy models to improve the characterization and understanding of metacommunity structure. Ecology 96(7): 1783–1792. https://doi.org/10.1890/14-1580.1
- Joseph MB, Stutz WE, Johnson PTJ. 2015. Multilevel models for the distribution of hosts and symbionts. PLoS ONE 11(11): e0165768. https://doi.org/10.1371/journal.pone.0165768

ii) ***Other Significant Publications and Products***

- Joseph MB, Knapp RA. 2018. Disease and climate effects on individuals jointly drive post-reintroduction population dynamics of an endangered amphibian. bioRxiv. https://doi.org/10.1101/332114
- Joseph MB, Mihaljevic JR, Orlofske SA, Paull SH. 2013. Does life history mediate changing disease risk when communities disassemble? Ecology Letters, 16(11): 1405-1412. https://doi.org/10.1111/ele.12180

Synergistic Activities:

- Developer of open source R packages smapr, eddi, leri, and neonaop, and open source python packages streamstats and earthpy.
- Lead instructor for a Bayesian statistics graduate seminar at CU Boulder, 2016
- Contributor to the probabilistic programming language Stan (documentation and case studies)
- Teaching assistant, Biometry, Fall 2015, CU Boulder
- Lead organizer for collaborative learning groups within Earth Lab, which foster new ideas, collaborations, feedback for ongoing week, and deep dives into analytical techniques, 2016-present

Imtiaz Rangwala
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Appointments

- Research Scientist II, CIRES, University of Colorado, Boulder (2013-)
- Climate Science Lead, DOI North Central Climate Adaptation Science Center (2015-)
- CIRES lead for Attribution & Predictability Assessment Team at NOAA ESRL PSD (2016-2018)
- Research Associate, Dept. of Marine and Coastal Sciences, Rutgers U., NJ (2011-2013)
- UCAR PACE Postdoctoral Fellow, Boulder (2009-2011)
- Lecturer, Dept. of Geography, Rutgers U., NJ (2009)

Education

Ph.D. (2008), Environmental Sciences, Rutgers University, NJ
M.S. (2003), Environmental Sciences, Rutgers University
B.S. (1999), Chemical Engineering, University of Mumbai, India

Research

- Drought and weather extremes
- Regional climate change & climate scenarios development for natural resource management
- Elevation dependent warming & climate change diagnostics in mountain regions
- Climate and hydrological projections in the Colorado River Basin

Publications (last three years)

Rangwala I., E. Palazzi and J. Miller (2019). Projected Climate Change in the Himalayas during the 21st Century. Chapter 4 in *Himalayan Weather and Climate and their impact on the environment,* edited by A. P. Dimri, B. Bookhagen, M. Stofeel and T. Yasunari. Springer Press (in press).

Hobbins M.T., **I. Rangwala**, J. J. Barsugli, and C. Dewes (2019), Extremes in evaporative demand and their implications for drought and drought monitoring in the 21st Century. Chapter 25 in *Extreme Hydrology and Climate Variability: Monitoring, Modeling, Adaptation and Mitigation*, edited by A. M. Melesse, W. Abtew, and G. B. Senay, Elsevier (in press).

Lyon N. J., D. M. Debinski and **I. Rangwala**. (2019). Evaluating the Utility of Species Distribution Models in Informing Climate Change-Resilient Grassland Restoration Strategy. *Frontiers in Ecology and Evolution*. doi: 10.3389/fevo.2019.00033.

Buono P., **I. Rangwala**, R. Rondeau and M. Bidwell (2018). Identifying Climate Refugia in the Spruce-Fir Ecosystem: Connecting Modeling Outputs with Field Characteristics and Managers' Needs in the Upper Gunnison Basin. *Mountain Views*, Vol. 12(2), Dec. 2018, pg 6-10. https://www.fs.fed.us/psw/cirmount/publications/pdf/Mtn_Views_dec_18.pdf

Hoell, A., J. Perlwitz, C. Dewes, K. Wolter, **I. Rangwala**, X.-W. Quan, J. Eischeid (2018), Anthropogenic Contributions to the Intensity of the 2017 United States Northern Great Plains

Drought. In *Explaining Extreme Events of 2017 from a Climate Perspective*, Bulletin of the American Meteorological Society. doi:10.1175/BAMS-D-18-0127.1

Rangwala I. and C. F. Dewes (2018). Downscaled climate projections at 800m spatial resolution for the north central United States based on the Multivariate Adaptive Constructed Analog (MACA) method from selective CMIP5 models. *ScienceBase,* doi.org/10.21429/C9704J.

Dole, R. M., Spackman, J. R.,...**I. Rangwala**…& Wolter, K. (2018). Advancing Science and Services during the 2015-16 El Niño: The NOAA El Niño Rapid Response Field Campaign. Bulletin of the American Meteorological Society, doi.org/10.1175/BAMS-D-16-0219.1

McNeeley S.M., C. Dewes, C. J. Stiles, T. Beeton, **I. Rangwala**, M. Hobbins, C. Knutson (2018). Anatomy of an interrupted irrigation season: Micro-drought at the Wind River Indian Reservation. *Climate Risk Management*, doi.org/10.1016/j.crm.2017.09.004

Hobbins, M.T., J. J. Barsugli, C. F. Dewes, and **I. Rangwala** (2017). Monthly Pan Evaporation Data across the Continental United States between 1950-2001. *ScienceBase,* doi.org/10.21429/C9MW25.

Dewes C., **I. Rangwala**, M. Hobbins, J. Barsugli and S. Kumar (2017). Drought risk assessment under climate change is sensitive to methodological choices for the estimation of evaporative demand. *PLoS ONE*, 12(3): e0174045. doi:10.1371/journal.pone.0174045

Climate Product Development & Outreach

- Landscape Evaporative Response Index: https://esrl.noaa.gov/psd/leri/
- Evaporative Demand Drought Index: https://esrl.noaa.gov/psd/eddi/

Selected Grants

- US Forest Service (2018) for "Analysis of climate and water flow data and long-term observed trends and future scenarios for a Vulnerability Assessment for the Pike-San Isabel National Forest"
- NIDIS/NOAA (2017) for "The Causes, Predictability and Historical Context of the 2017-18 Northern Plains Drought"
- USGS NCCSC & Colorado State University (2017) for "Evaporative Demand, Drought Monitoring and Assessment across Timescales: Climate Foundational Sciences & Services for DOI's North Central Climate Science Center"
- USACE/SERDP (2017) for "Proposal to process, disseminate and add value to the NACORDEX simulations for use by the impacts and adaptation communities to produce pilot study analyses in two US subregions, and statistical downscaling evaluations using NA-CORDEX"
- USGS NCCSC & Colorado State University (2014) for "Evaporation, Drought, and the Water Cycle Across Timescales: Climate Foundational Sciences for the North Central Climate Science Center"
- NOAA Sectoral Applications Research Program (2014) for "Balancing Severe Decision Conflicts under Climate Extremes in Water Resource Management" http://sciencepolicy.colorado.edu/research_areas/bsdc/index.html

United States Department of the Interior

NATIONAL PARK SERVICE
Climate Change Response Program
1201 Oakridge Drive
Fort Collins, CO 80525

February 25, 2019

RE: Proposal to Develop Climate Scenarios Toolbox (NC CASC)

To Whom It May Concern,

The NPS Climate Change Response Program has been advocating and using climate change scenario planning for more than a decade, and it has conducted more than 30 scenario workshops. We have now mainstreamed the use of climate scenarios into other planning processes, including the Resource Stewardship Strategies that will be produced for each of the more than 400 park units. So we are *very heavily invested* in the acquisition, processing, analysis, visualization, and presentation of climate data and climate scenarios.

Acquiring and processing climate data has been a substantial and ongoing challenge for us, and we've worked with the North Central CSC (now CASC) on this for years. We must be responsive to new climate data sets, to better ways to visualize and present results, to include new metrics (e.g. water balance, human comfort, etc.), and we need to have a robust, reliable, and extremely efficient way to produce presentation-quality materials for 15-20 workshops each year. I.e., for us, this is core and operational, not a research or one-off exercise.

The challenges we (NPS) face are in no way unique, but they are common to virtually every organization or team that needs to develop and communicate site-specific climate data, customized to the resources, audience, and circumstances. Some existing tools provide part of the functionality we need, but the weak link is support of multiple scenarios that are based on resource-relevant variables. The proposed project is designed specifically to meet this need, and as such it will be extremely useful to us. We will participate fully in the project and we will help define user needs, develop specifications, use cases, and provide feedback throughout the project. We will invite project members to participate in workshops so they can experience how we present materials, and how park managers react to products. We feel this "real life" experience is critical for developers to fully understand and meet our needs.

We're excited about the prospect to have a professionally-designed and implemented toolkit, available to all, which we can use to better serve our parks.

Best regards,

John E Gross

Dr. John E. Gross

Ecologist, NPS Climate Change Response Program

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Mountain-Prairie Region

IN REPLY REFER TO:
FWS/R6/

MAILING ADDRESS:
Post Office Box 25486
Denver Federal Center
Denver, Colorado 80225-0486

STREET LOCATION:
134 Union Boulevard
Lakewood, Colorado 80228-1807

February 25, 2019

Dr. Leslie Hsu
Coordinator, Community for Data Integration
Core Science Systems
U.S. Geological Survey

Re: Letter of support for the proposal "Open-source and open-workflow Climate Scenarios Toolbox for adaptation planning"

Dear Dr. Hsu,

The USFWS (Region 6) is pleased to provide a support letter for the proposal submitted by Bamzai et al "Open-source and open-workflow Climate Scenarios Toolbox for adaptation planning". The USFWS Ecological Services Program in Region 6 (SD, ND, NE, KS, MT, WY, CO, UT) is actively involved in generating Species Status Assessments (SSAs) for numerous species across the region. These science based documents provide the backbone for helping FWS leadership make informed decisions on whether or not a species should be listed under the Endangered Species Act as threatened or endangered. A significant component of the SSA process is the projected "future condition" of the species. Future condition is one of the most challenging aspects of the SSA as it is dependent on climate scenarios with varying levels of uncertainty, modeled habitat impacts based on climate scenarios, etc. The USFWS routinely reaches out to experts in other agencies (i.e. NOAA, USGS, etc.) and universities (i.e. University of Colorado) for help in the climate change aspects of future condition, most recently for the North American wolverine and many others.

There are several benefits that would be provided by the Climate Scenarios Toolbox to the FWS: 1) Being able to choose the extent of analysis (i.e. a specific species range), 2) produce climate change results at higher spatial resolutions (i.e. 4km) for the species range, and 3) new products that go beyond temperature and precipitation. There have been numerous requests from our field office biologists to be able to customize climate variables and projections based on species ranges and the need for higher spatial resolution results from what is currently available. We believe the project described by Bamzai et al would be a most welcome step forward in helping the FWS gain a better understanding of species' future conditions and ultimately aid leadership in making informed listing decisions to help us achieve our conservation mission.

Sincerely,

John Guinotte

John Guinotte, Ph.D.
Spatial Ecologist
Ecological Services
U.S. Fish and Wildlife Service
Mountain Prairie Region 6
134 Union Blvd., Lakewood, CO 80228
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AK CASC
Alaska Climate Adaptation Science Center

To: Dr. Leslie Hsu, Coordinator, Community for Data Integration, and reviewers for FY2019 CDI RFP

Dr. Hsu-

I'm writing to recommend for funding in FY2019 the proposal by USGS Lead PI Bamzai and others, "Open-source and open-workflow Climate Scenarios Toolbox for adaptation planning." The proposed project intends to develop a toolbox for use by mission-driven boundary organizations that provide information for resource management and decision-making. These organizations face the need to respond to an increasing diversity of users, often with severely limited resources, but also to avoid one-size-fits-all approaches that ignore the variations and unique requirements of new applications. There is therefore a growing need for both standardization of analytical approaches and for customization of workflows in such work because the scientific foundation requires replicability even as the need to modify and tailor tools to new users' needs grows.

The proposed activities and products in PI Bamzai's project would meet these needs and create the foundation of a user community that could greatly benefit from increased synergy in the theoretical and practical development of stakeholder-driven products. The development of a community of practice around the proposed Toolbox has the potential to increase the coherence and customizability of co-production projects around the country. If it had existed 5 years ago, I am certain my own work would have evolved in a considerably different fashion because I would have time freed up to do the more important tasks of elicitation and analysis rather than focusing on one-off analyses. I expect there are many potential users out there like me, and many more coming up through the ranks of agencies, who would benefit from this Toolbox and be able to maximize their contributions to the work of adaptation and vulnerability assessment. As the next round of Coupled Model Intercomparison Project (CMIP6) climate model outputs become available, there is considerable need within DOI and other federal agencies to spend less time re-analyzing and re-adapting old code to update or re-answer questions that have already been addressed. These products could result in considerable timesavings and increase the capacity to focus on what really matters – the impacts on and responses of our Nation's manage resources.

In short, I think this project could go far in helping the community of climate impacts, adaptation, and vulnerability analysts leap ahead in the next few years.

Sincerely,

Dr. Jeremy S. Littell
USGS Research Ecologist
Lead Scientist, Alaska Climate Adaptation Science Center
Anchorage, AK

Community for Data Integration (CDI)
Data Management Plan for Full Proposals

Instructions: Fill out all relevant fields of the following tables to help your team plan for your project's data management and product communication needs. For more guidance on data management plans, see the *USGS Data Management Website*, specifically the *Data Management checklist*. All products resulting from CDI projects must comply with the *Office of Science Quality and Integrity Instructional Memoranda* on data management.

Data Inputs	
Title	**Source/URL**
Multivariate Adaptive Constructed Analogs Dataset	https://climate.northwestknowledge.net/MACA/index.php

Data Processing	
Access and Sharing	Data will be accessed and subset per each use case using OPeNDAP access to the Northwest Knowledge Network THREDDS server.

Proposed Products (repeat table for multiple products)	
Title	Climate Scenarios Toolbox code
Product Type	*Source Code*
Description	Git Hub repositories for two R packages comprising version 1.0 of the Climate Scenarios Toolbox, including R vignettes and other user guidance
Format	R packages
Data Volume Estimate	
Backup & Storage	Code will be shared openly on Git Hub and will eventually be submitted to rOpenSci.
Metadata	
Repository for Product	Git Hub / rOpenSci
Communication Plan	The team will make the Toolbox discoverable by disseminating information via the North Central CASC website, the National CASC website and electronic newsletter, and by sharing across other USGS platforms such as ScienceBase. Additionally, the team will work with other climate service providers in the CASC network and CASC stakeholder partners to disseminate information about the Toolbox.

CDI Product Type Vocabulary

Data Release: A formal USGS data release that will go through FSP review and approval
Mobile Application: Interactive application built specifically for a mobile device
Presentation: Slides, video, or other presentation media
Publication: Peer-reviewed publication (USGS or external journal publication)
Software: Executable or compiled code that can be downloaded
Source Code: A code repository for the project's source code

Web Application: Interactive application that runs on a web browser
Web Link: Project webpage, wiki page, white paper, or online resources that do not fit other categories
Web Service: A service endpoint URL where your service can be accessed by a client application

Community For Data Integration (CDI) RFP BUDGET FORM

Budget Category	Federal Funding "Requested"	Matching Funds "Proposed"
GRAND TOTAL:	$29,600	$30,841
Do not edit the rows above this line.		
1. PERSONNEL (SALARIES including benefits):		
Personnel:		
Bamzai, 80 hrs at $#/hr		$5,830
Miller, 80 hrs at $#/hr		$4,450
Joseph, 80 hrs at $#/hr		$5,435
Rangwala, 80 hrs at $#/hr		$7,916
Contract Personnel :		
Student Contractor, 600 hrs at $23.19/hr	$13,914	
Student Contractor, 600 hrs at $23.19/hr	$13,914	
Total Salaries:	$27,828	$23,631
2. TRAVEL EXPENSES:		
Trip to Wind Cave NP, 4 days, 3 travelers		
Per Diem:	$1,772	
Transportation (Airfare + Mileage/Shuttle):		
Other expenses (e.g. registration fees):		
Total Travel Expenses:	$1,772	$0
3. OTHER DIRECT COSTS: (itemize)		
Equipment (inc. software, hardware, purchases/rentals):		
Publication Costs:		
Office supplies:		
Training:		
Other expenses (specify):		
Total Other Direct Costs:	$0	$0
Total Direct Costs:	$29,600	$23,631
Indirect Cost:		$7,210